OTT Quarterly Analytic Program Review

March 31, 1998

Analytic Team

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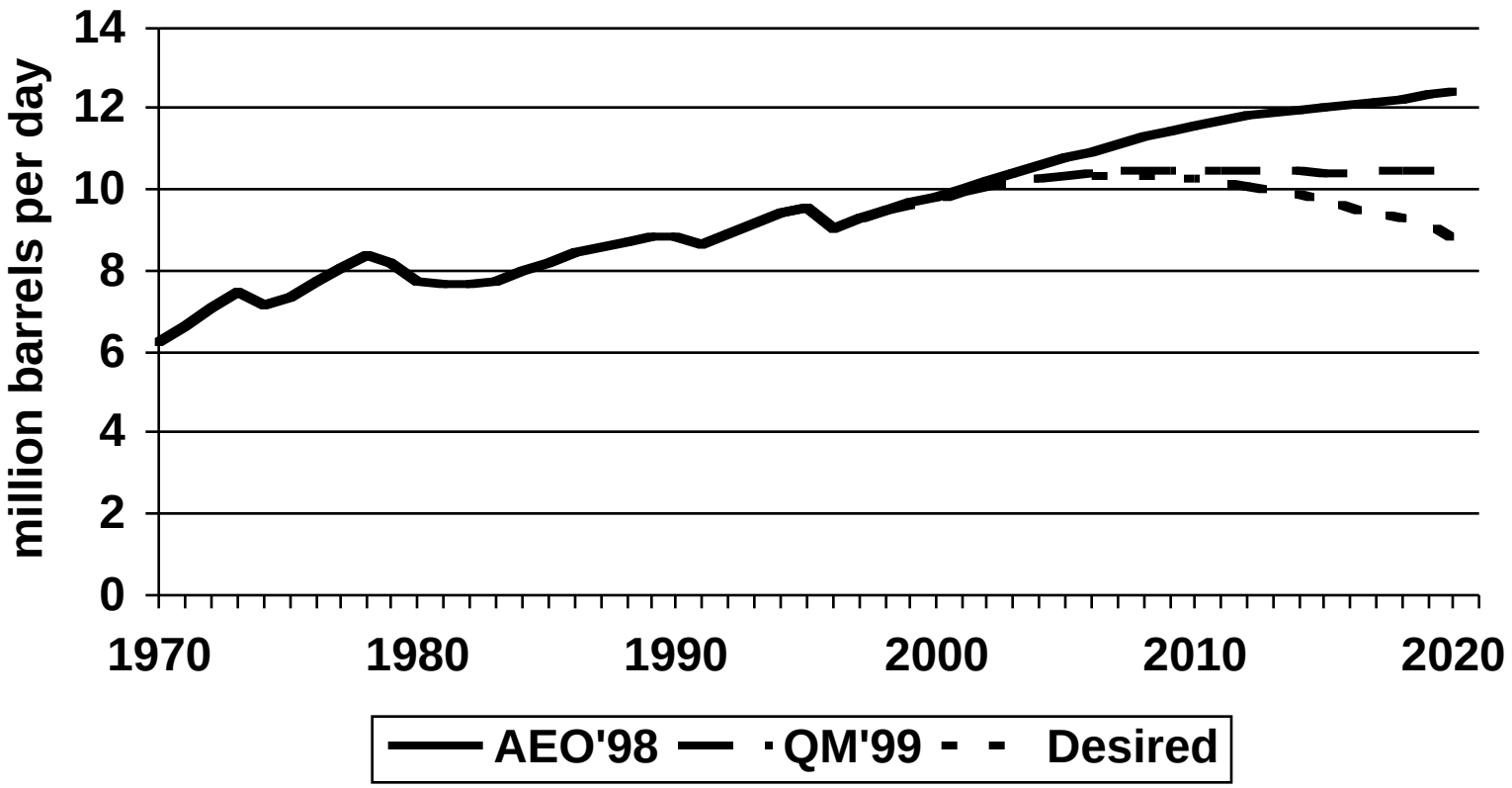
Projected Highway Fuel Use



QM'99 Oil Displacement

	2010		2020	
	MMB/D	%	MMB/D	%
Substitution	0.84	7.3%	1.11	8.9%
Efficiency	0.29	2.5%	0.86	6.9%
Total	1.13	9.8%	1.97	15.8%

Efficient Light Vehicles 2020

	Percent	Oil Reduction (%)	Incremental Cost (%)
Diesel	23.1%	31%	5-7%
HEV	5.3%	43%	5-10%
Fuel Cell	3.3%	52%	10-15%

HEV Cost Model
Argonne National Laboratory

Overview: Spreadsheet model that estimates HEV cost in comparison to CV costs

Representative Inputs:

- Vehicle production schedule vs. time
- Battery type/characteristics
- Vehicle configuration
- Vehicle energy conversion efficiency
- Electrical energy cost

HEV Cost Model
Sample Output

Argonne National Laboratory: Center for Transportation Research

A Methodology for Projecting Parallel Hybrid Electric Vehicle Cost

(All costs are in 1995 dollars)

HEV (Parallel configuration) Life-Cycle Amortized Cost Analysis

Vehicle type: **Midsize Car**

Battery type: **Nickel metal hydride**

HEV Production Level	< 5,000	25,000	100,000	>250,000
Item	**2005**	**2007**	**2010**	**2020**
Purchase Price				
Conventional Vehicle	$ 22,070	$ 22,522	$ 23,200	$ 25,620
Hybrid Electric Vehicle				
Common components	$ 15,953	$ 16,279	$ 16,769	$ 18,519
Additional aluminum cost	$ 2,250	$ 2,070	$ 3,600	$ 1,200
Auxiliary Power Unit	$ 2,584	$ 2,632	$ 2,447	$ 2,464
Generator	$ 599	$ 540	$ 389	$ 356
Inverter & Power Electronics	$ 2,275	$ 1,604	$ 1,041	$ 874
Motor	$ 599	$ 540	$ 389	$ 356
Transmission	$ 943	$ 917	$ 805	$ 783
System control	$ 420	$ 403	$ 380	$ 341
Other body parts	$ 398	$ 386	$ 375	$ 364
Additional HVAC Cost	$ 114	$ 109	$ 102	$ 102
First Battery Price	$ 2,094	$ 1,881	$ 1,398	$ 1,159
Total HEV Price	$ 28,228	$ 27,362	$ 27,696	$ 26,517
Operating Cost				
Conventional Vehicle				
Fuel cost (c/mi)	5.69	5.72	5.76	5.86
Non-fuel cost (c/mi)	4.90	4.93	4.93	5.20
Total cost (c/mi)	10.59	10.65	10.70	11.06
Hybrid Electric Vehicle				
Electricity cost (c/mi)	-	-	-	-
Fuel cost (c/mi)	2.24	2.09	1.94	1.72
Non-fuel cost (c/mi)	5.03	5.58	5.06	5.89
Battery cost (c/mi)	6.62	5.58	4.20	4.01
Total cost (c/mi)	13.89	13.25	11.20	11.63
Life-cycle Cost				
Conventional Vehicle				
Purchase Price (c/mi)	21.66	21.77	22.10	24.41
Operating Cost (c/mi)	10.59	10.65	10.70	11.06
Less Scrappage Value (c/mi)	(0.14)	(0.14)	(0.14)	(0.15)
Total Life-cycle Cost (c/mi)	32.12	32.29	32.67	35.32
Hybrid Electric Vehicle				
Purchase Price (c/mi)	25.64	24.63	25.06	24.16
Operating Cost (c/mi)	13.89	13.25	11.20	11.63
Less Scrappage Value (c/mi)	(0.16)	(0.15)	(0.15)	(0.15)
Total Life-cycle Cost (c/mi)	39.37	37.73	36.10	35.64
Important HEV Parameters				
Motor power (kW)	29	28	23	22
APU power (kW)	47	48	42	40
Generator power (kW)	29	28	23	22
Battery power (kW)	36	34	27	26
Battery energy (kWh)	3.2	3.0	2.5	2.3
Battery mass (kg)	75	69	55	47
Estimated all-elec range (mi)	11	11	12	12

Preliminary HEV Cost Results (Midsize Car)

YEAR	Production Level	Incremental Cost
2005	5,000	28%
2007	25,000	21%
2010	100,000	19%
2020	250,000	3.5%

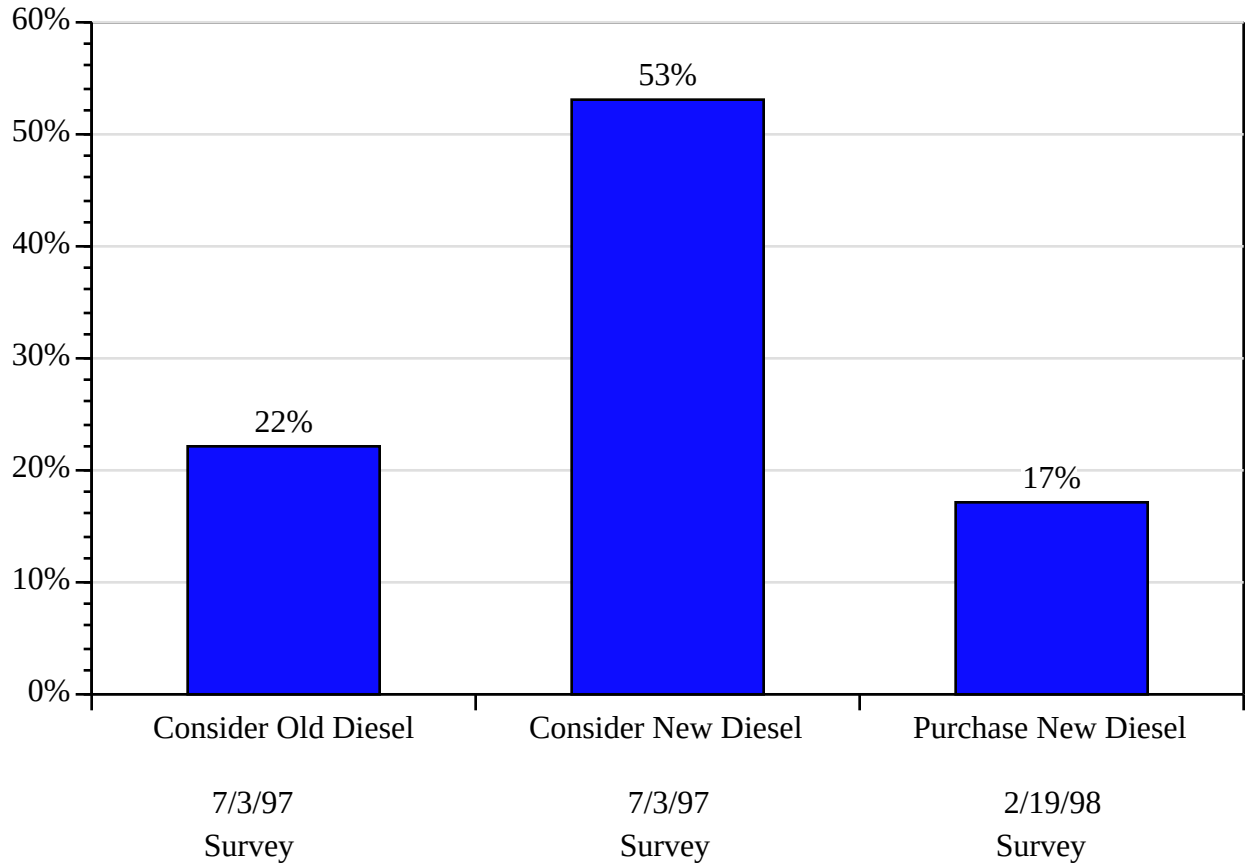
Comparison of Model Results to QM 99

Vehicle Type	Status	Year	ANL Cost Analysis				QM 99			
			Conventional Vehicle Purchase Price	HEV Purchase Price	Cost Differential	Cost Ratio	Cost Ratio	Conventional Vehicle Purchase Price	HEV Purchase Price	Cost Differential
Small Car	Introduction	2008	$ 16,778	$ 22,228	$ 5,450	1.32	1.10	$ 15,200	$ 16,720	$ 1,520
	Maturity	2015	$ 17,980	$ 21,303	$ 3,323	1.18	1.10	$ 15,200	$ 16,720	$ 1,520
Midsize Car	Introduction	2001	$ 22,070	$ 28,228	$ 6,158	1.28	1.15	$ 23,200	$ 26,680	$ 3,480
	Maturity	2010	$ 23,200	$ 27,696	$ 4,496	1.19	1.05	$ 23,200	$ 24,360	$ 1,160
Passenger Truck	Introduction	2011	$ 25,000	$ 30,211	$ 5,211	1.21	1.12	$ 22,190	$ 24,852	$ 2,662
	Maturity	2015	$ 26,280	$ 29,210	$ 2,930	1.11	1.10	$ 22,190	$ 24,409	$ 2,219

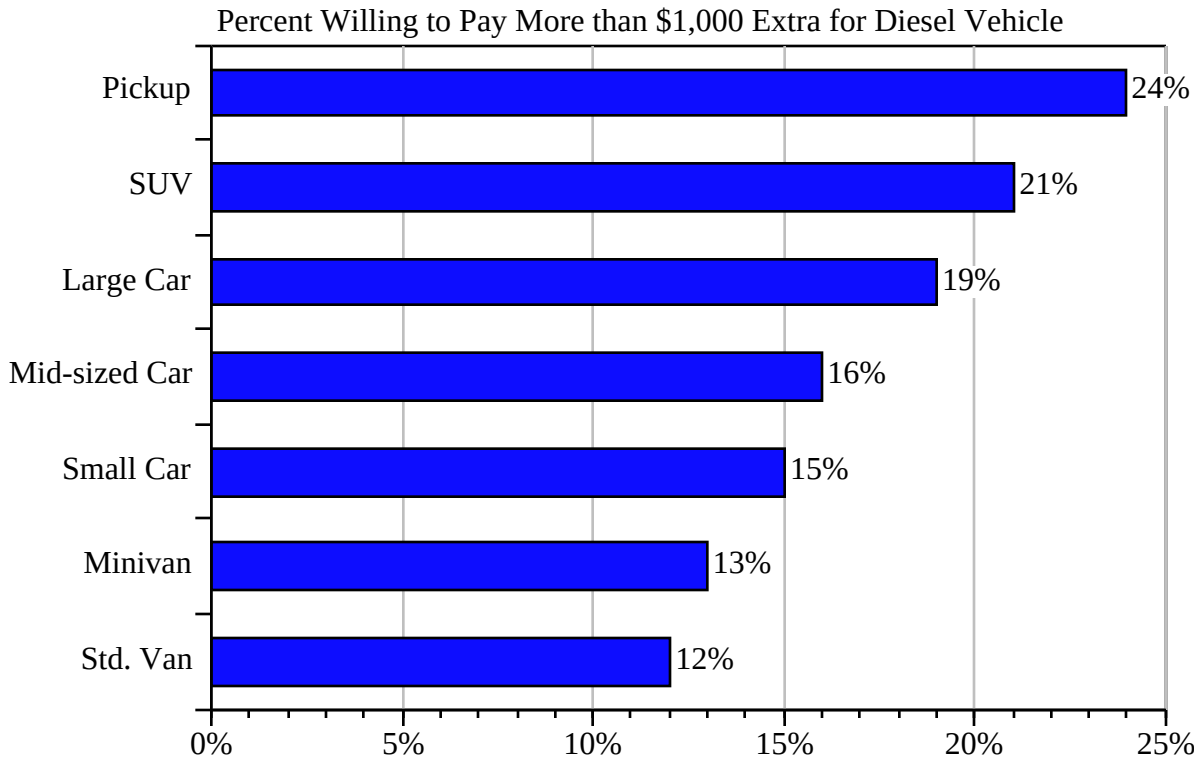
Light Truck Share of Light Vehicle Sales

	Percent
1970	15
1975	21
1980	21
1985	27
1990	33
1995	41
1996	43
1997	45
1998	48 (2 months)

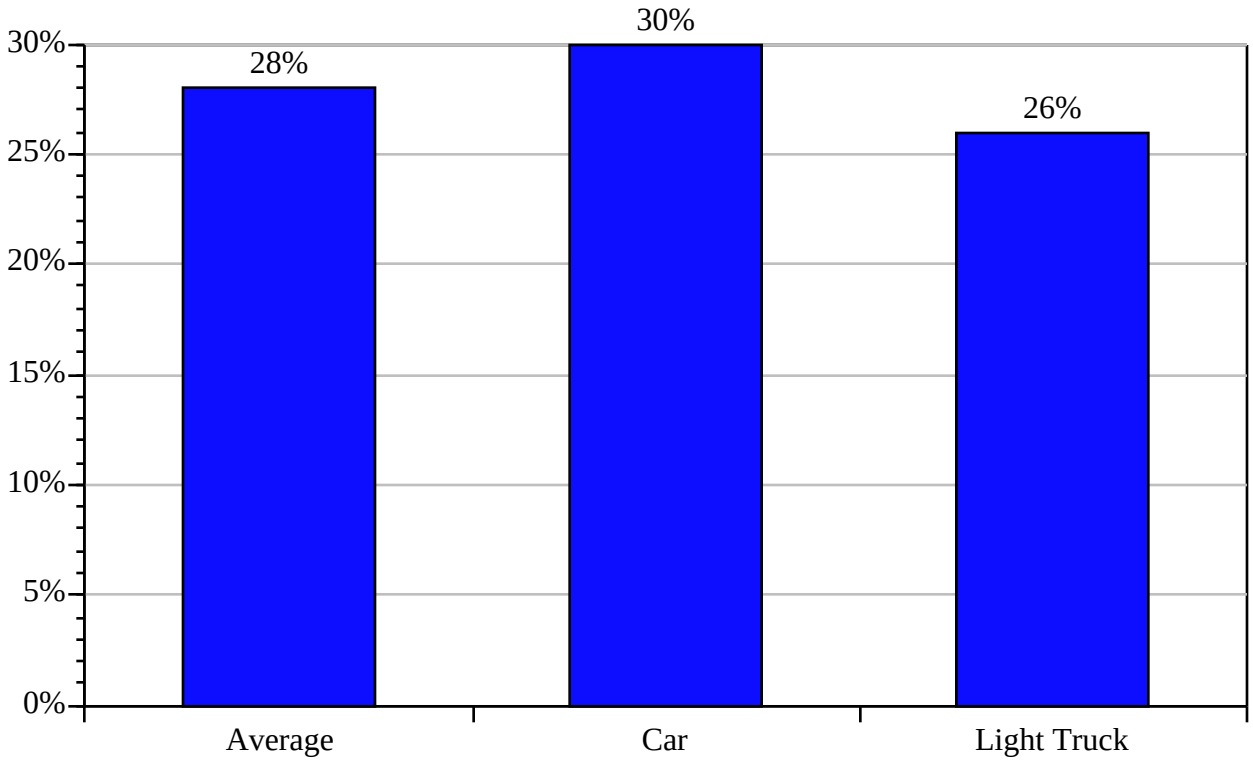
Diesel Surveys: "Consider" Does Not Equal "Purchase"



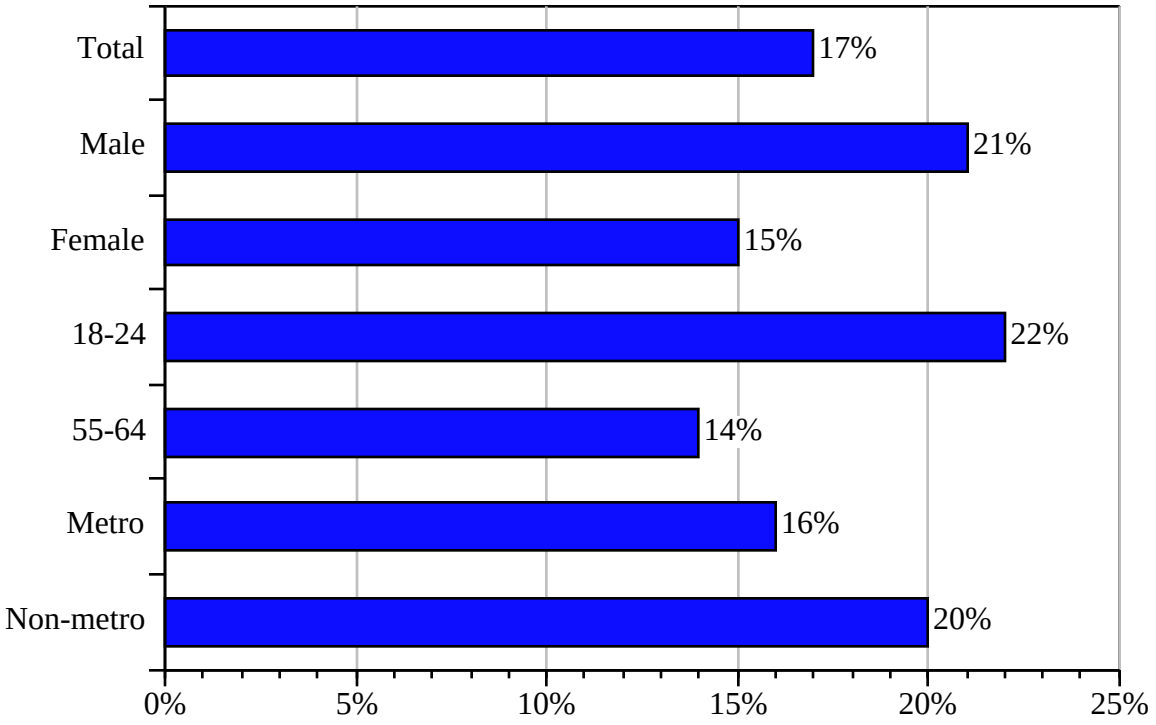
Willingness to Pay More than $1,000 Extra by Vehicle Type



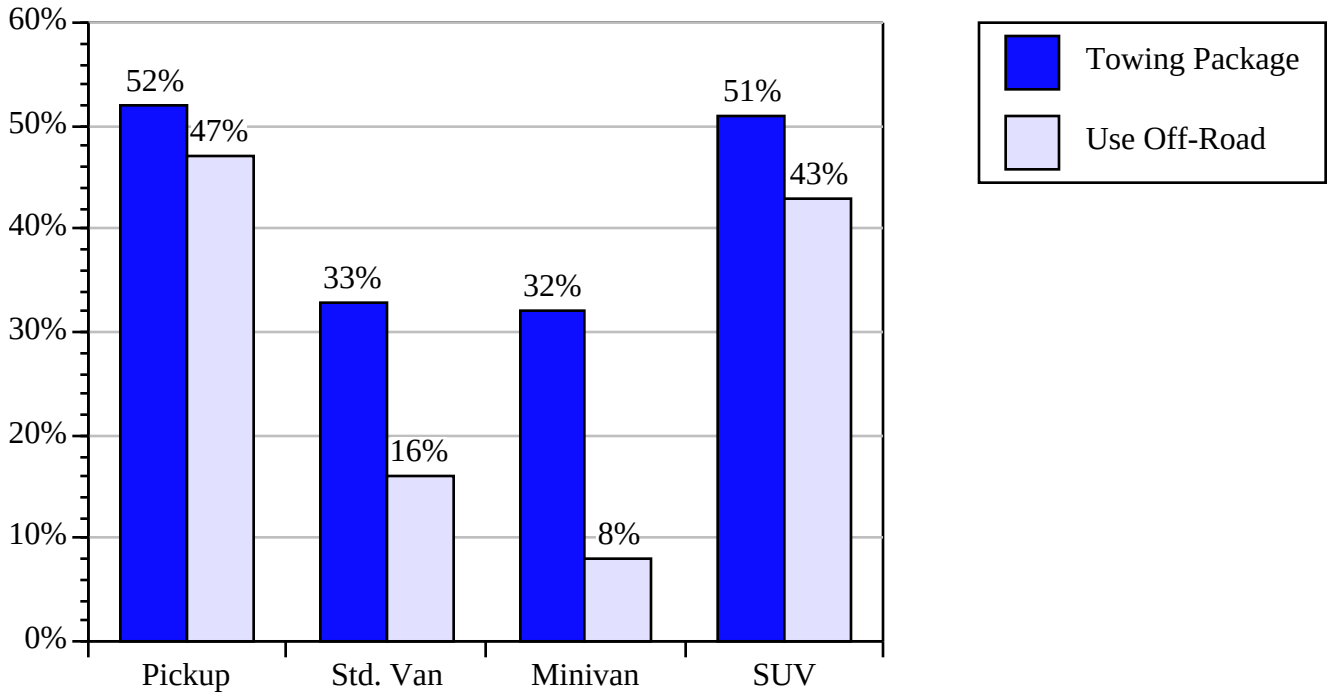
QM Diesel Penetration Results for 2010



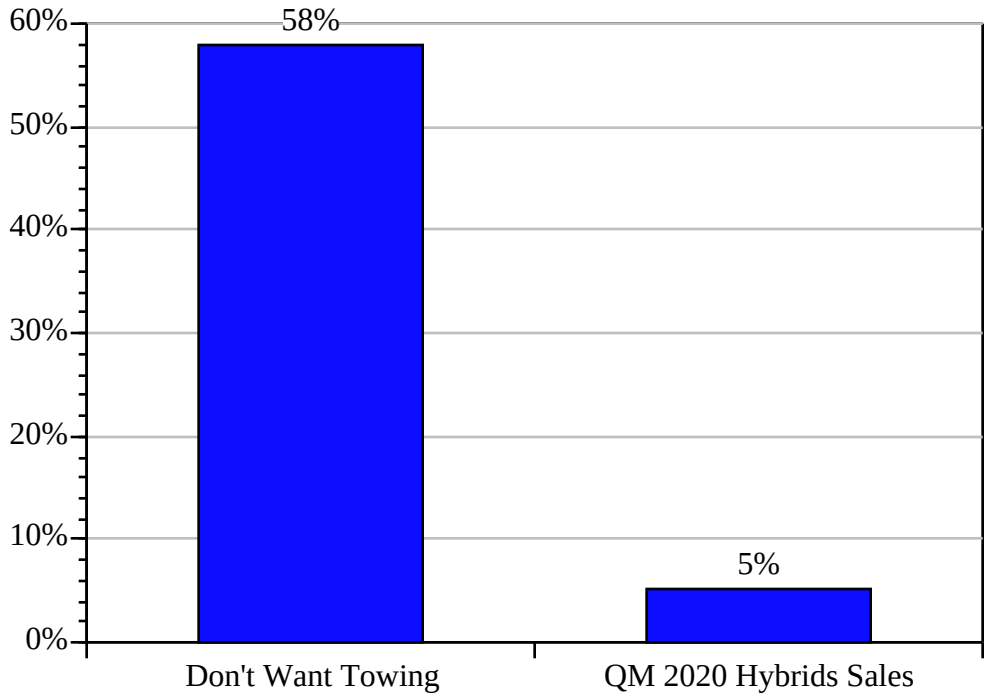
Willingness to Pay More than $1,000 Extra by Demographics



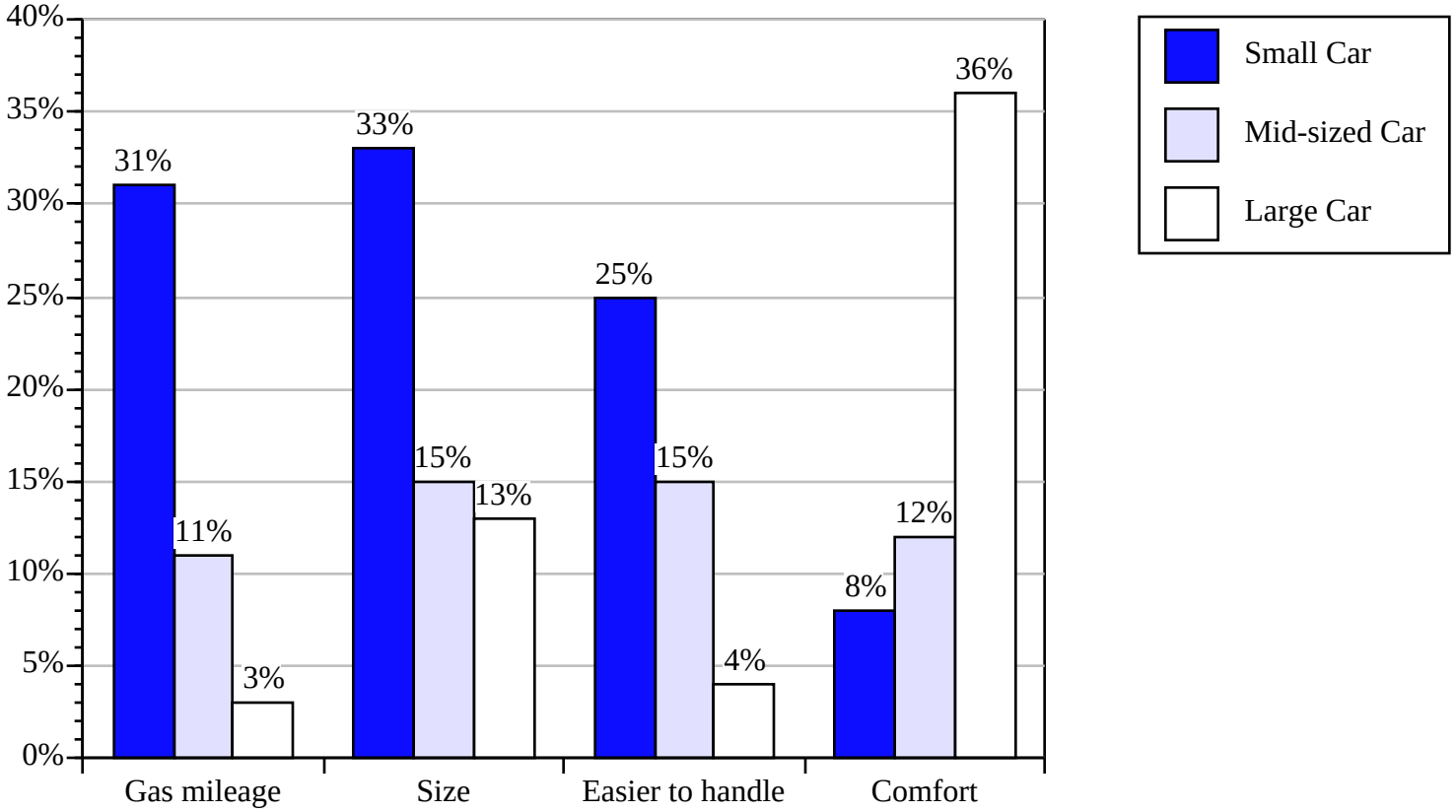
Plan to Purchase Towing Package or Use Off-Road



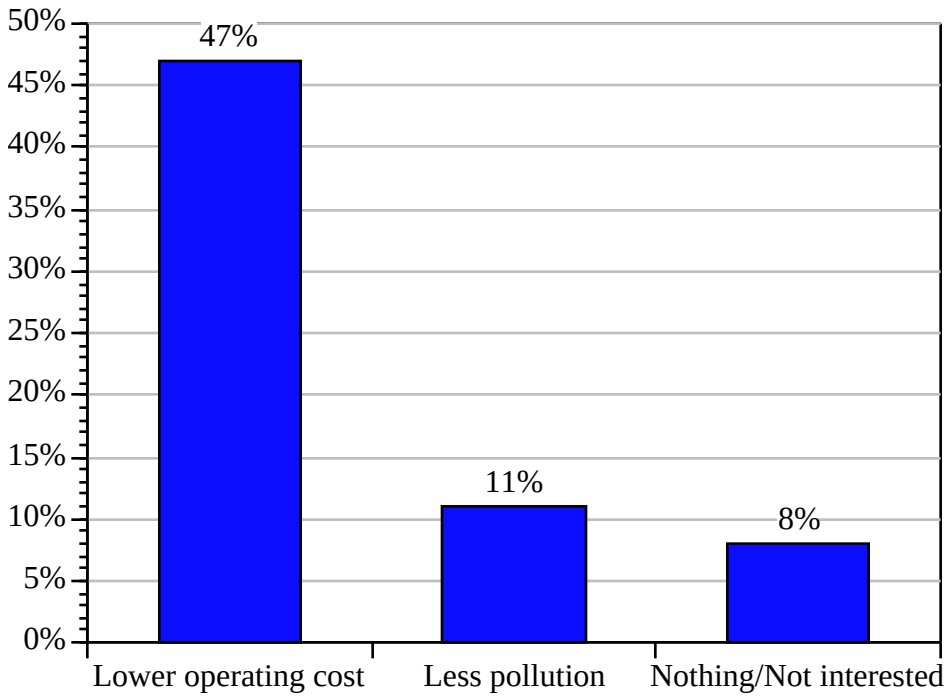
Passenger Trucks and Towing



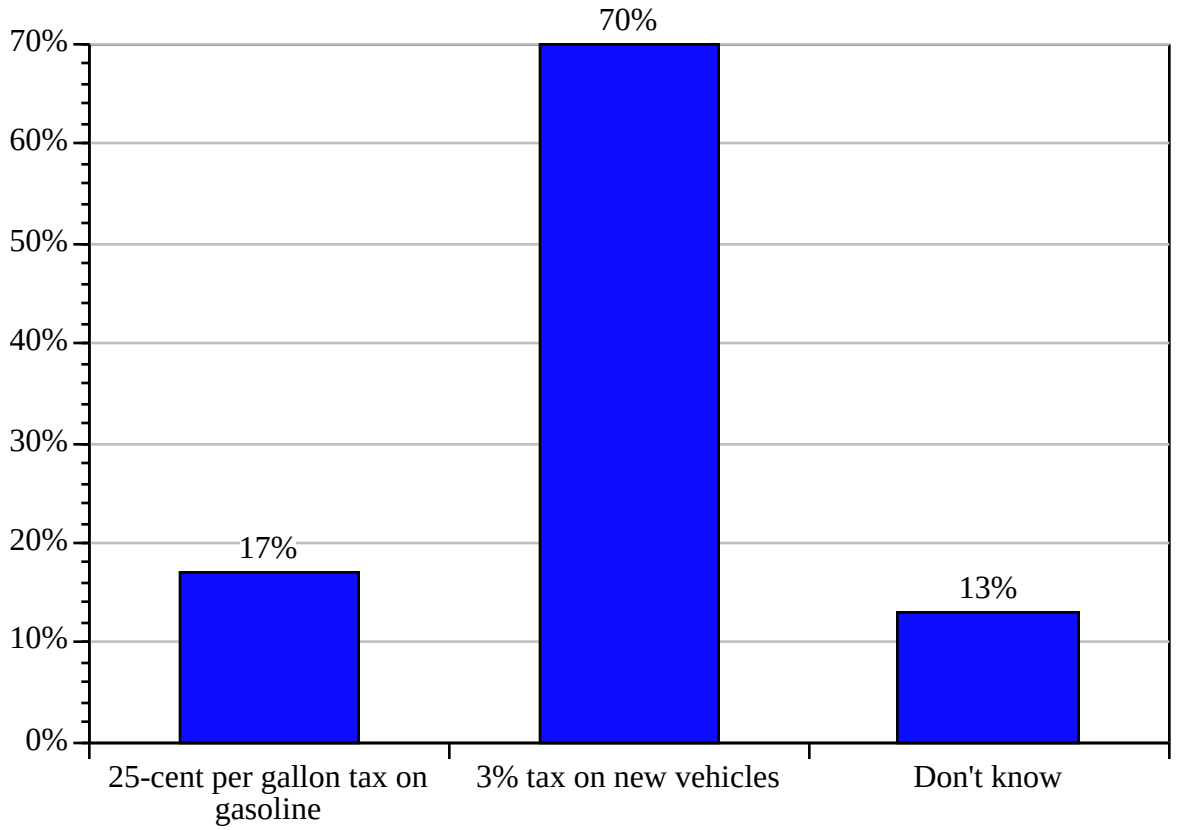
Why People Select Cars Over Trucks



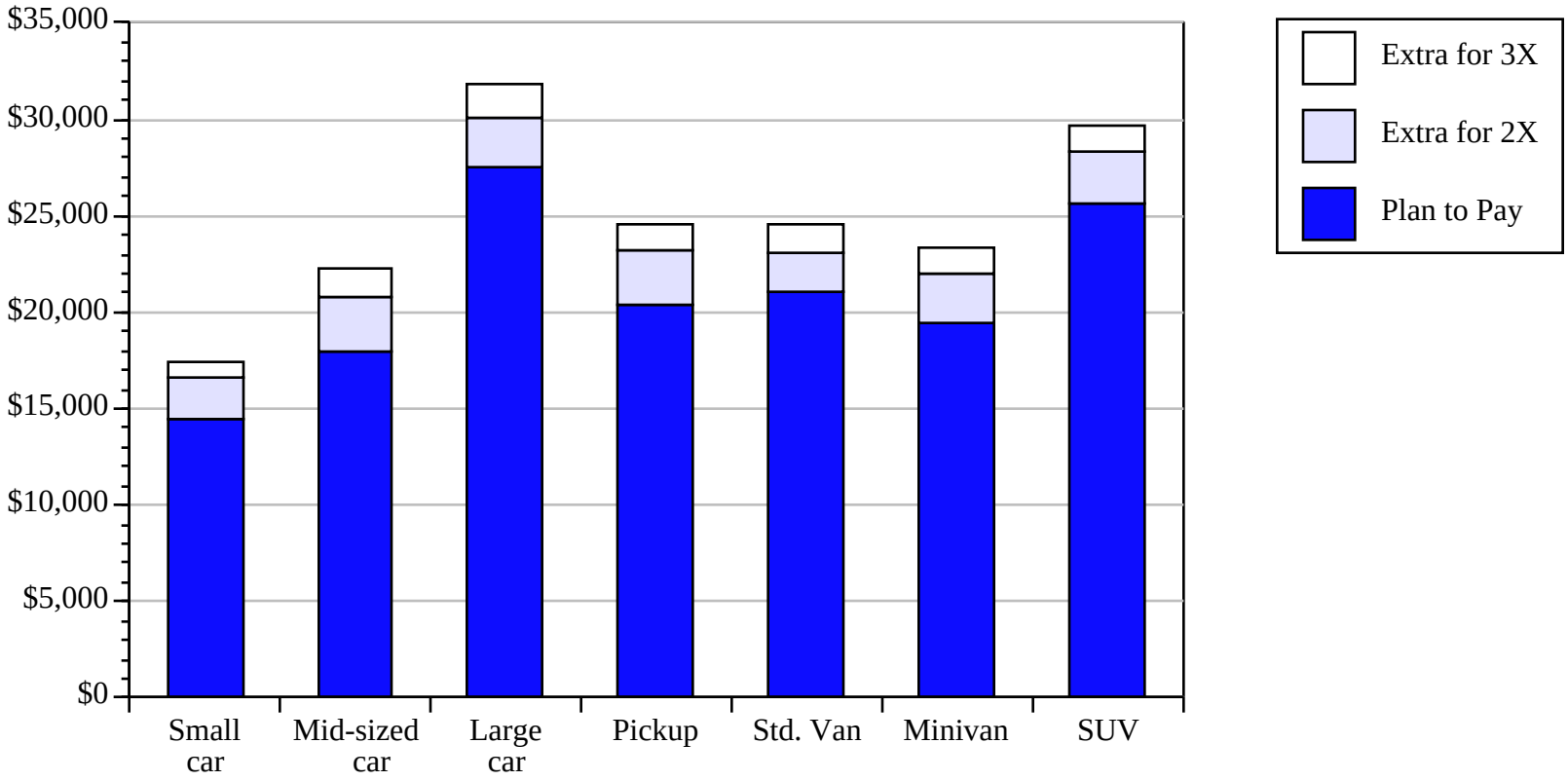
Motivation for Purchasing Higher MPG Vehicle



Preference Between Two Greenhouse Gas Policies

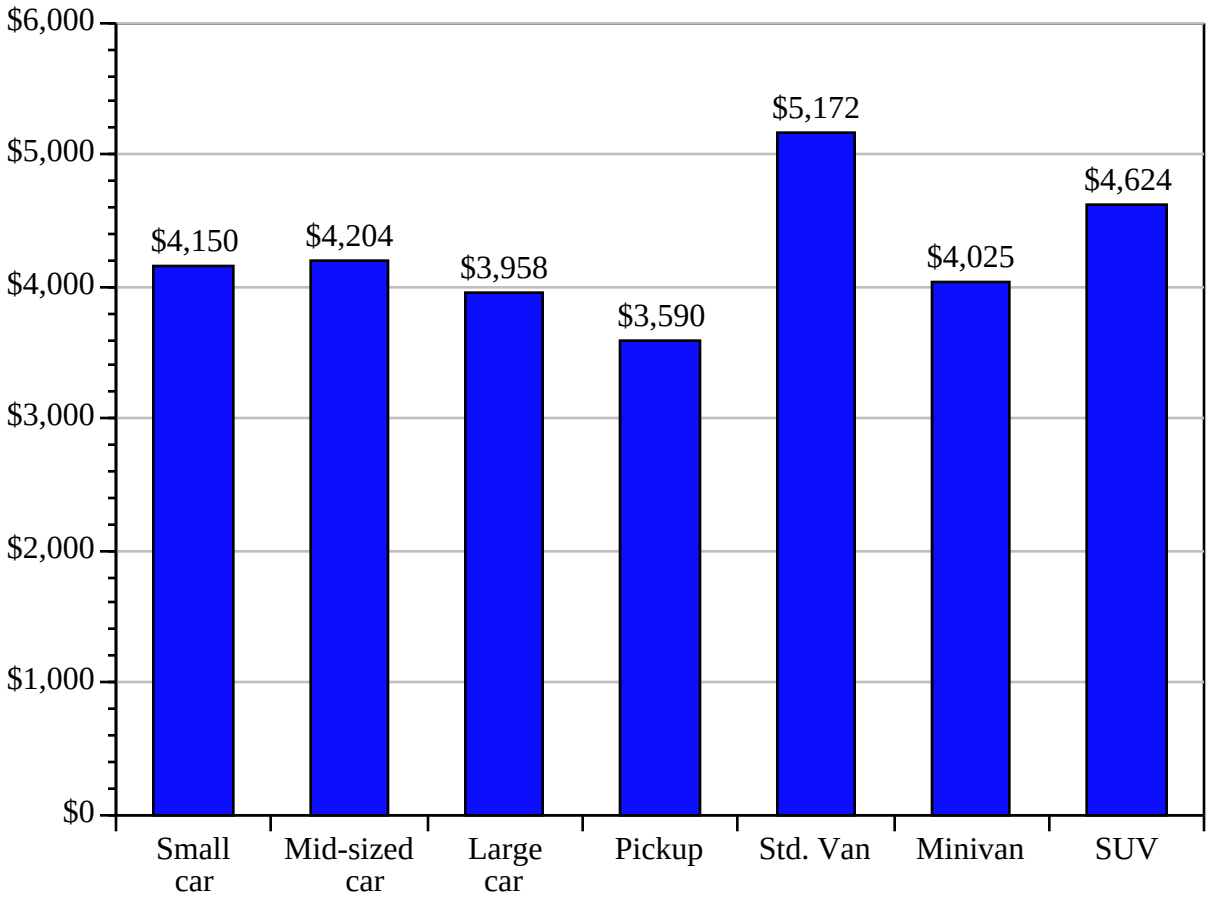


Willingness to Pay Extra for 2X and 3X Vehicles

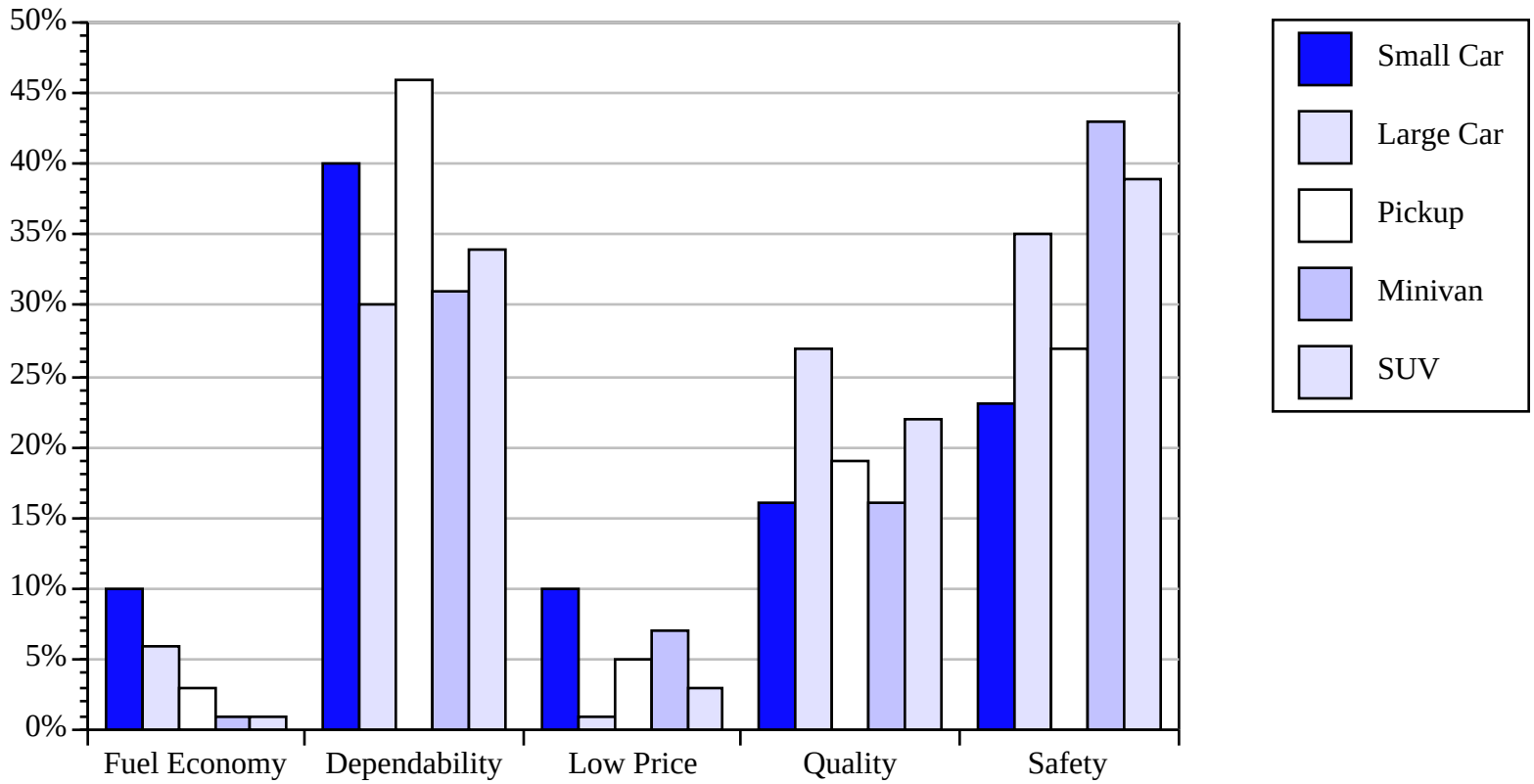


Note: increments are cumulative

Price Increase Required Before People Decide to Buy Used



Vehicle Attribute Preference

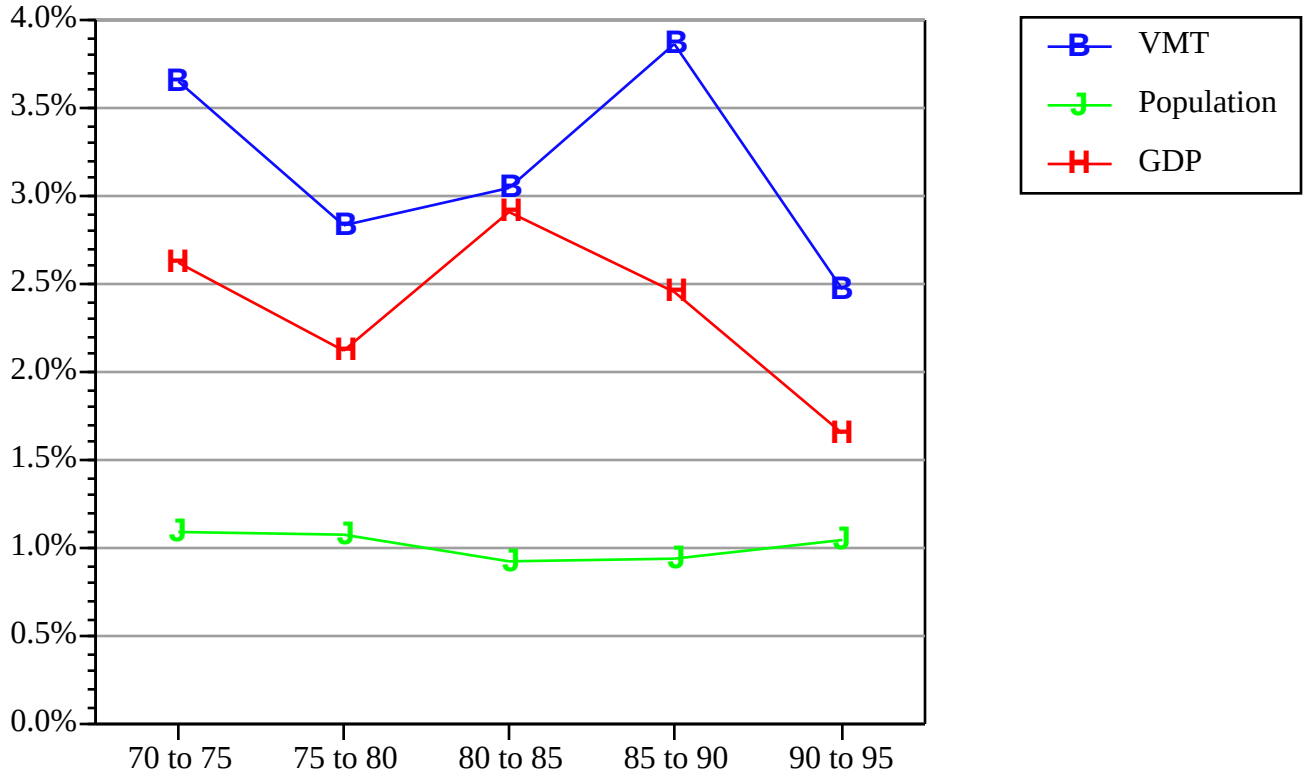


Historic Annual Growth Rates for VMT, Population, and GDP (current $)

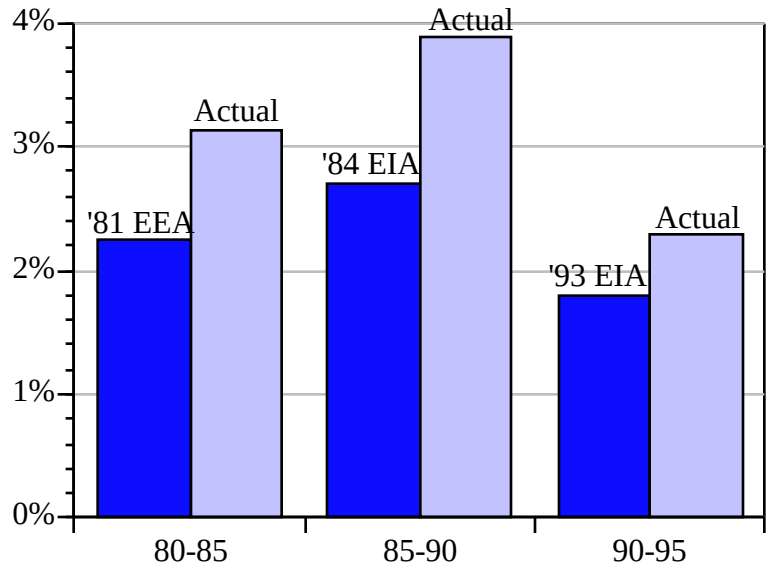
Interval	VMT (% per year)	Population (% per year)	GDP (% per year)
1970 to 75	3.65%	1.10%	2.62%
1975 to 80	2.84%	1.07%	2.12%
1980 to 85	3.04%	0.92%	2.91%
1985 to 90	3.86%	0.94%	2.46%
1990 to 95	2.47%	1.05%	1.66%
Trend (1970-95)	3.17%	1.02%	2.35%

Source: Stacy C. Davis, Oak Ridge National Laboratory, Transportation Energy Databook: Edition 17, ORNL-6919, August 1997; U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, April 1997.

Historic Annual Growth Rates for VMT, Population, and GDP (current $)



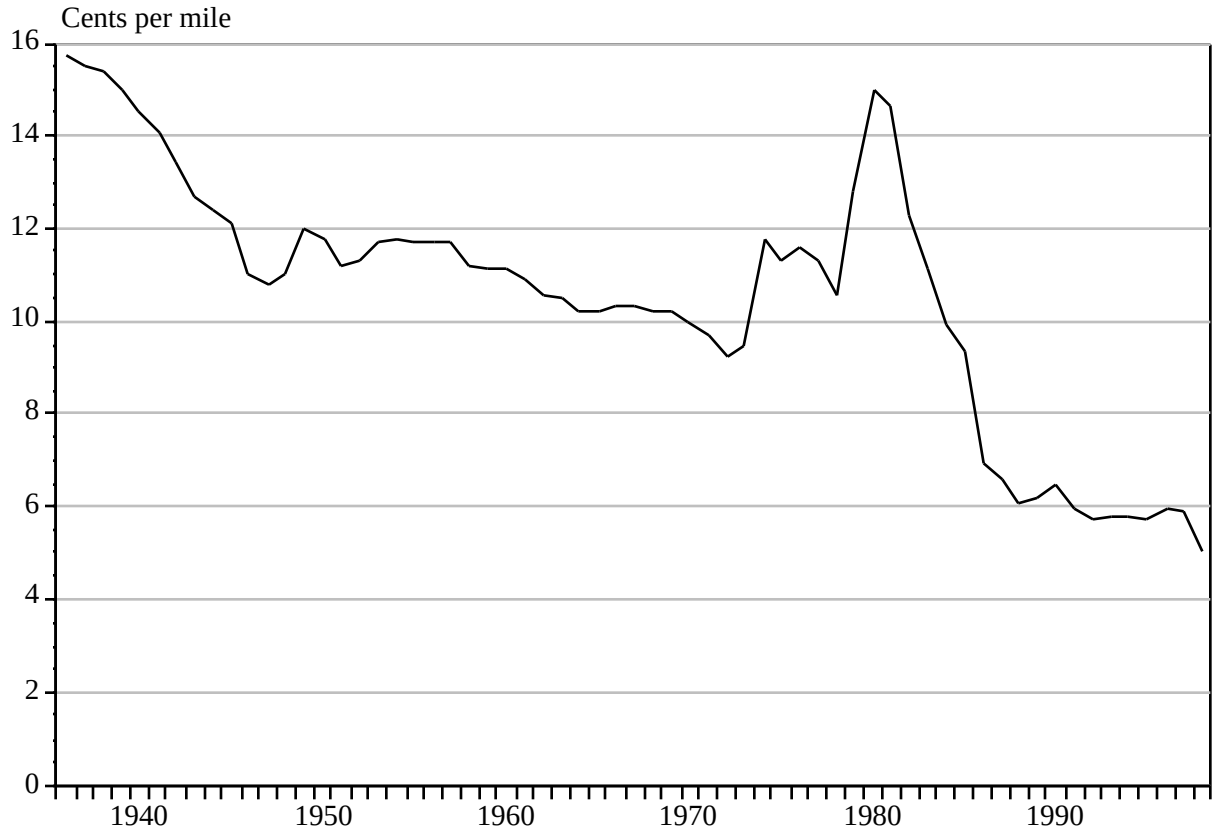
Actual v. Estimated VMT Growth Rates



Source: John German, EPA, Factors Affecting VMT Growth, March 17, 1997.

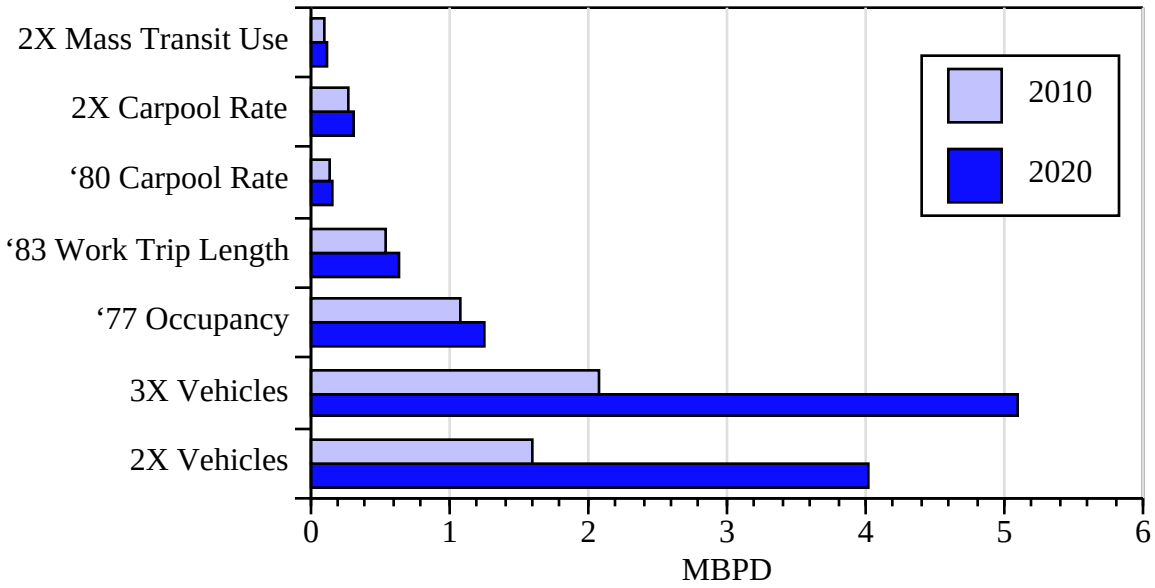
Big Graph

Fuel Cost of Driving a Mile ($1996) 1936 to 1998



Source: Gasoline costs were divided by on-road vehicle fuel economy. Data for gasoline costs: 1936-1946 = API; 1947-1948 = extrapolation; 1949-1996 = EIA. Prices were for leaded gasoline from 1936 to 1975 and unleaded gasoline thereafter. Fuel economy data: 1936-1959 = Highway Statistics, DOT/FHA; 1960-1996 = EIA.

Comparison of Potential Fuel Savings from Fuel Economy Improvements and VMT Reduction (MBPD)



Sustainability

- Reducing U.S. dependence on finite fossil fuels, especially petroleum
- Reduce the burden of importing energy, especially from insecure sources
- Declining GHG's per unit of travel over time
- Take criteria air emissions from transportation out of the environmental equation

Sustainability

- Keep transportation affordable. Expenditures for transportation should not exceed historical (20%) levels
- Maintain the fiscal integrity of public expenditures for transportation (ensure adequate highway trust fund and affordable public transportation expenditures)
- Ensure access for all citizens (especially low income, elderly, and disadvantaged)

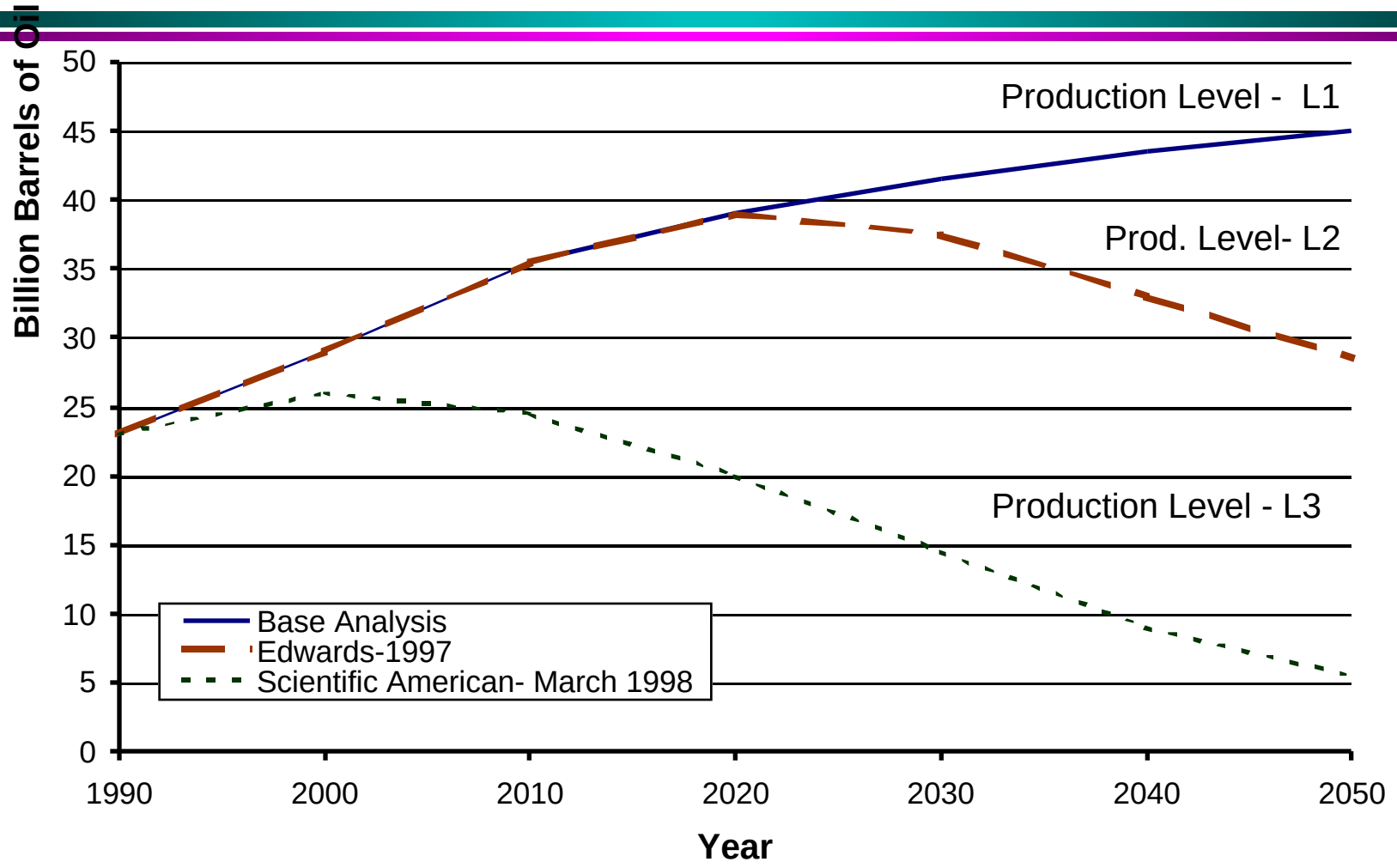
2050 Study Options

- Options:
  1. Ethanol from biomass resources and wastes
  2. Fischer-Tropsch fuels from natural gas
  3. Hydrogen from wind
  4. Electricity (3 fuel mixes: renewables-dominated, nuclear-dominated, and coal-dominated)
- Cases:
  1. 1/3 ETOH, 1/3 Fischer-Tropsch, 1/3 Hydrogen
  2. 1/3 ETOH, 1/3 Fischer-Tropsch, 1/3 Electricity

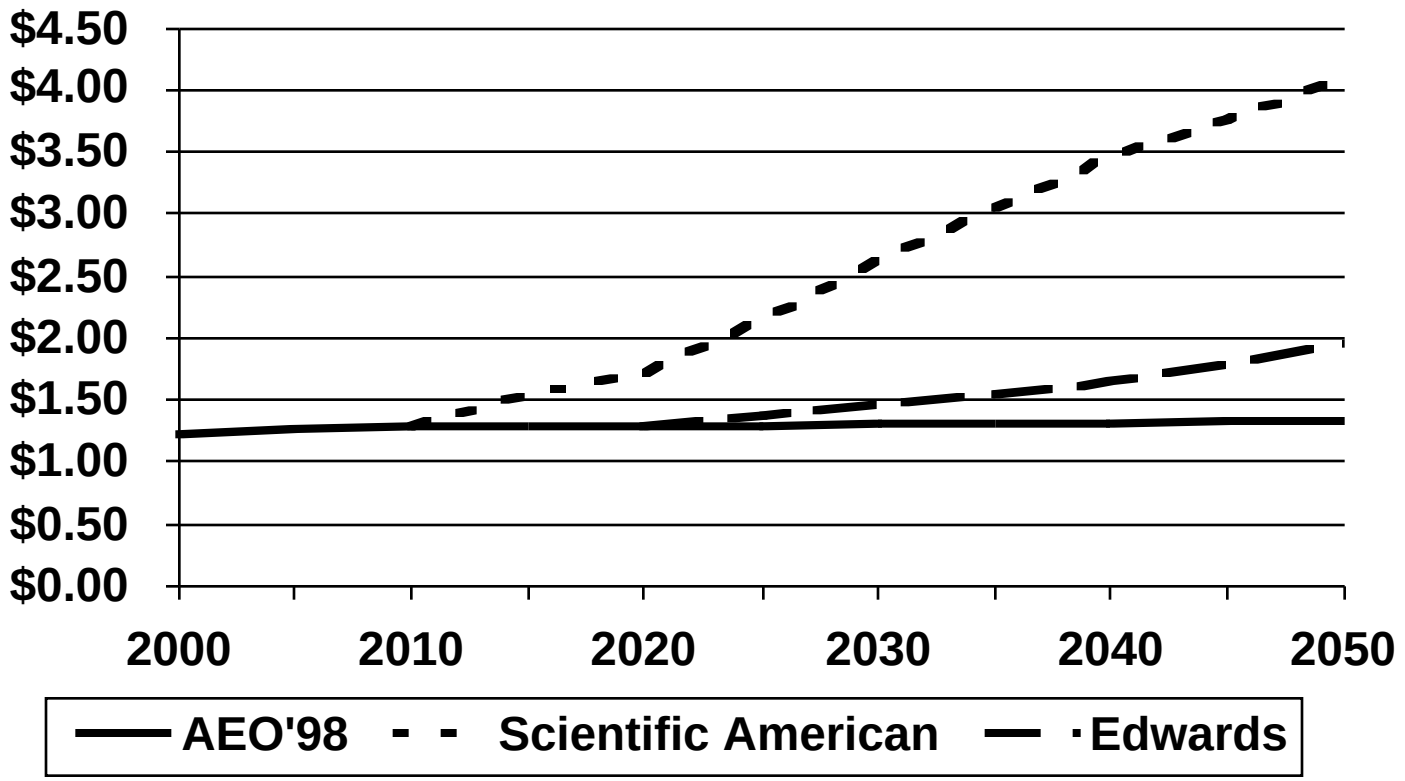
2050 Base Case Projections

	1997	2050
Population (millions)	268.5	393.9
GDP (billion $)	7165	16768
LDV Sales (millions)	12.5	16.9
LDV Stock (millions)	180.1	300.0
LDV VMT (billions)	2330	4638
LDV Energy Use (quads)	14.8	25.7
LDV Carbon Emissions (MMTCe)	287	505
Percent New Car Sales	55%	51%

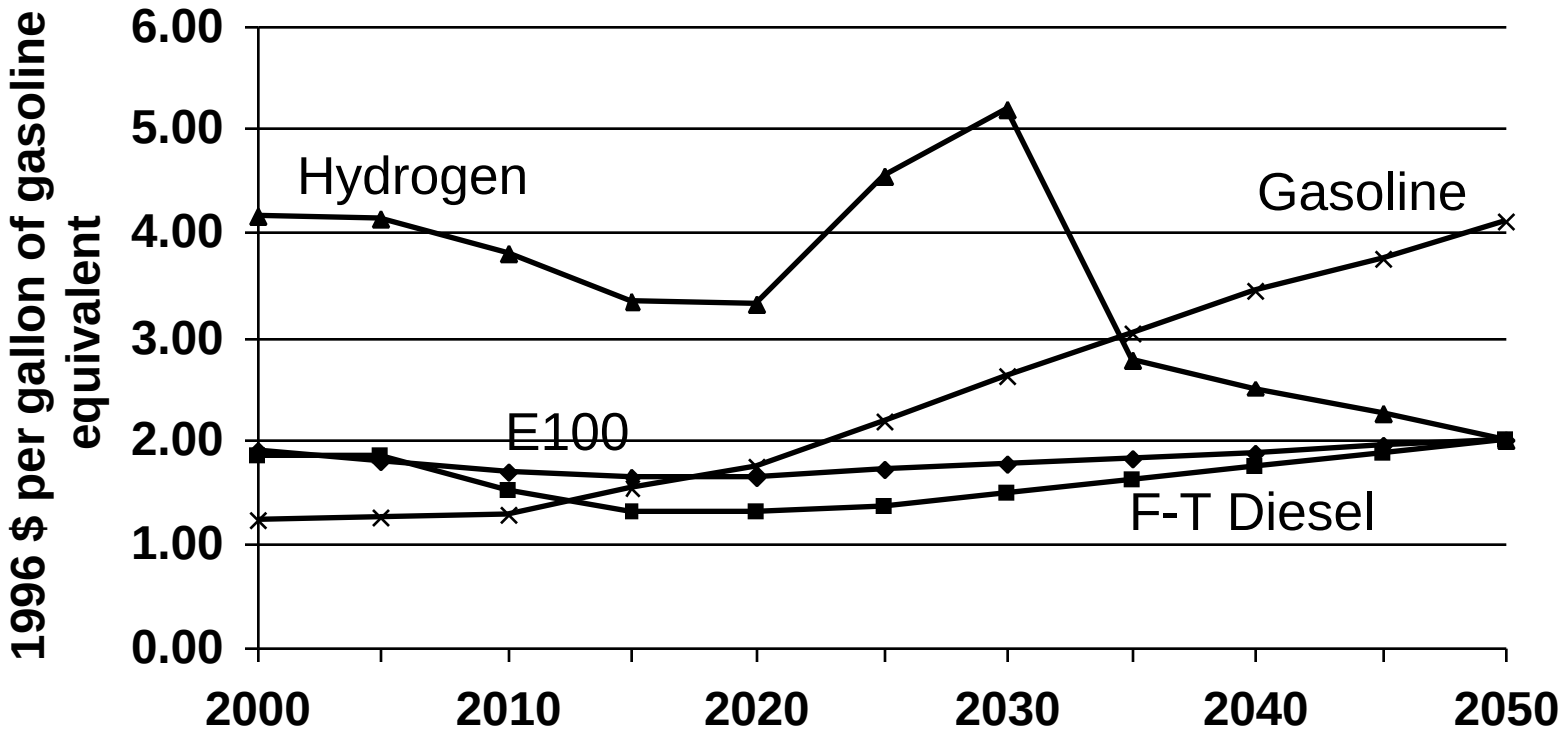
World-Wide Oil Production Projections



Estimated Fuel Prices For Projected Reserves



Fuel Prices

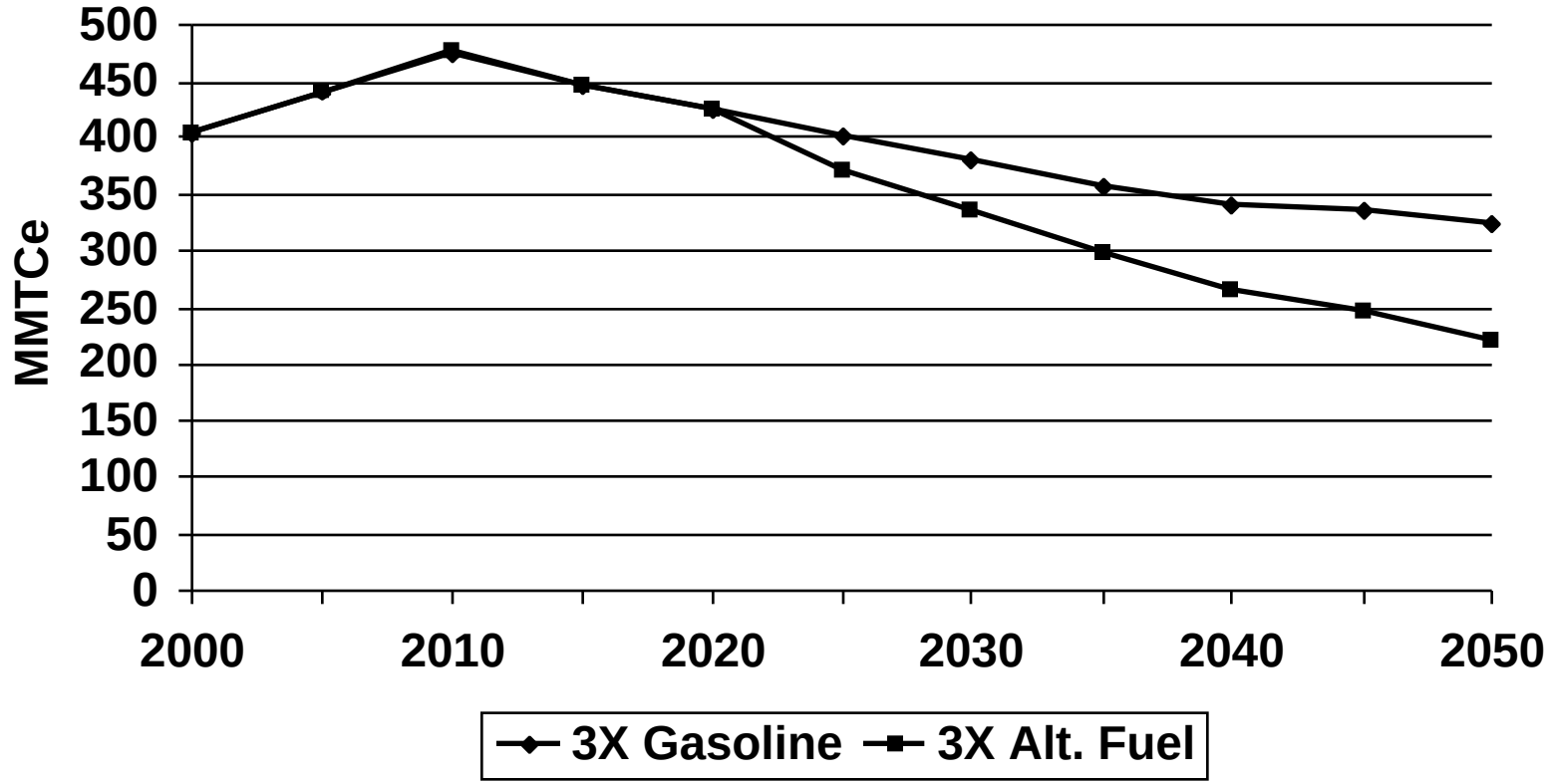

1996 $ per gallon of gasoline equivalent
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2000
2010
2020
2030
2040
2050
Hydrogen
Gasoline
E100
F-T Diesel

Estimation of 2050 Fuel Cost

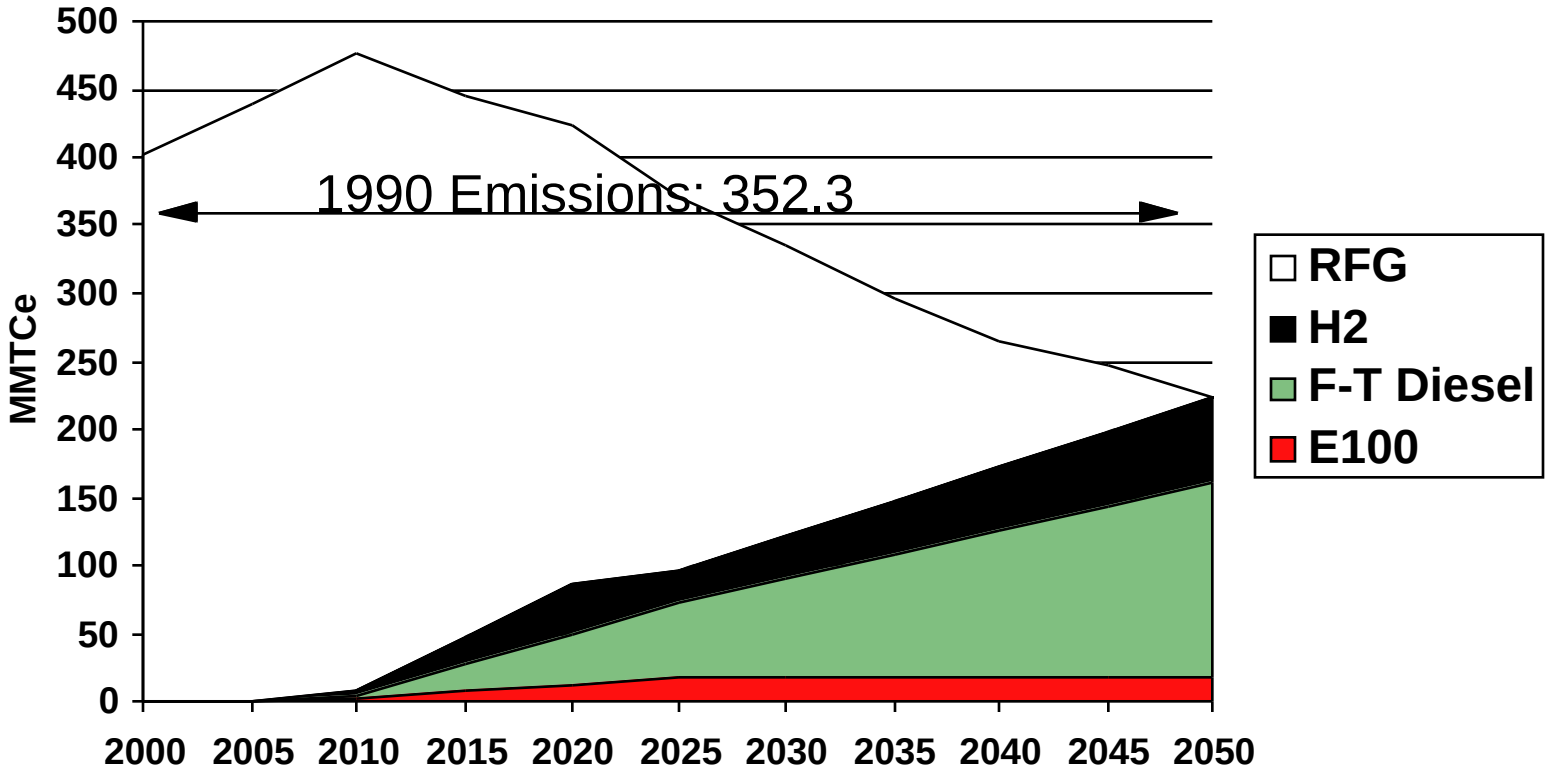
	Production	Distribution	Service Station	Taxes	Total ($/gale)
RFG	3.004	0.106	0.087	1.003	4.20
E100	0.850	0.169	0.120	0.861	2.00
F-T Diesel	0.491	0.102	0.087	1.320	2.00
H2	0.740	0.588	0.234	0.438	2.00

Ref: M. Singh & K.Stork with revisions by Lab. Team

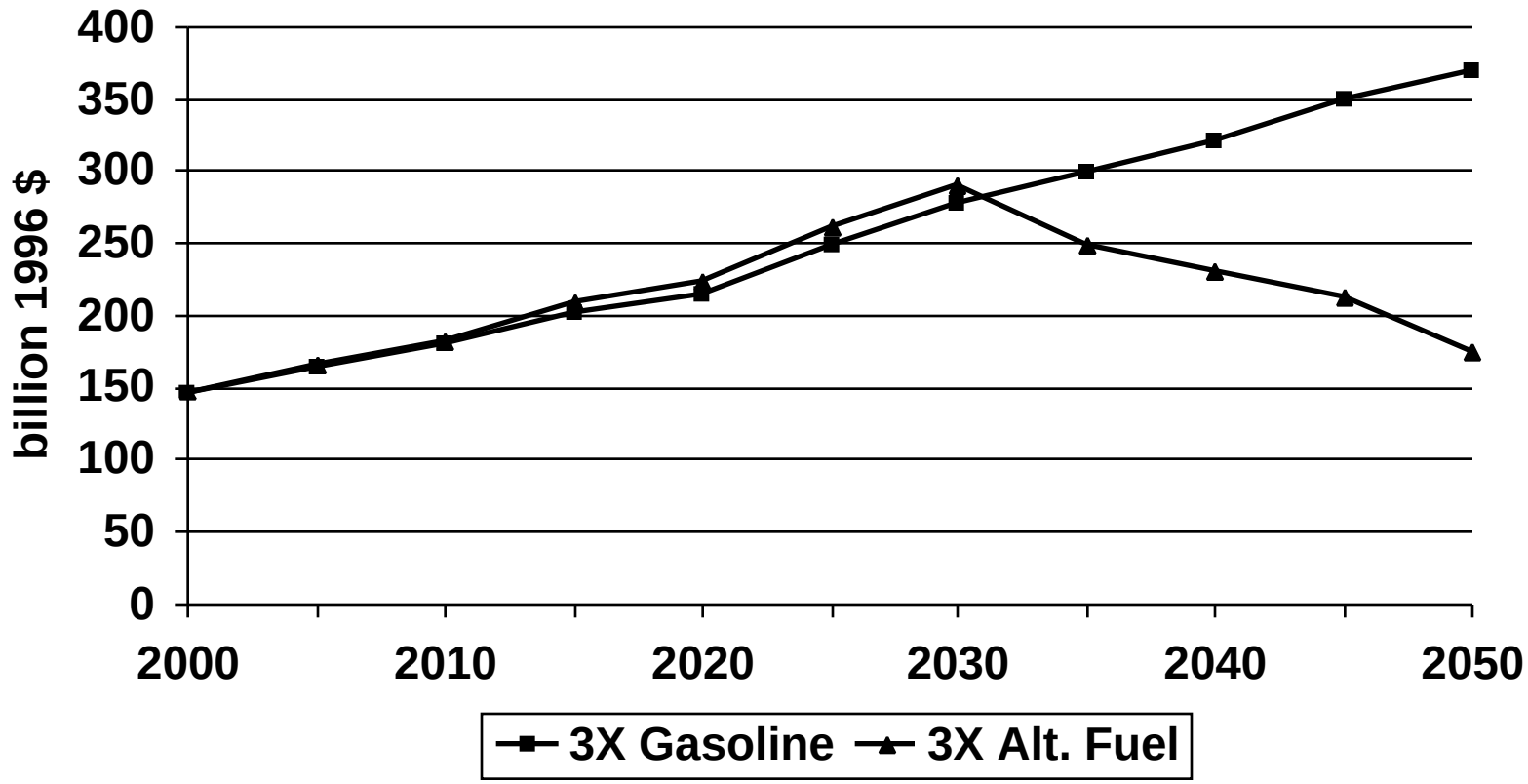
Full Fuel Cycle Carbon Equivalent Emissions



Carbon Equivalent Emissions by Fuel Source



Fuel Expenditures



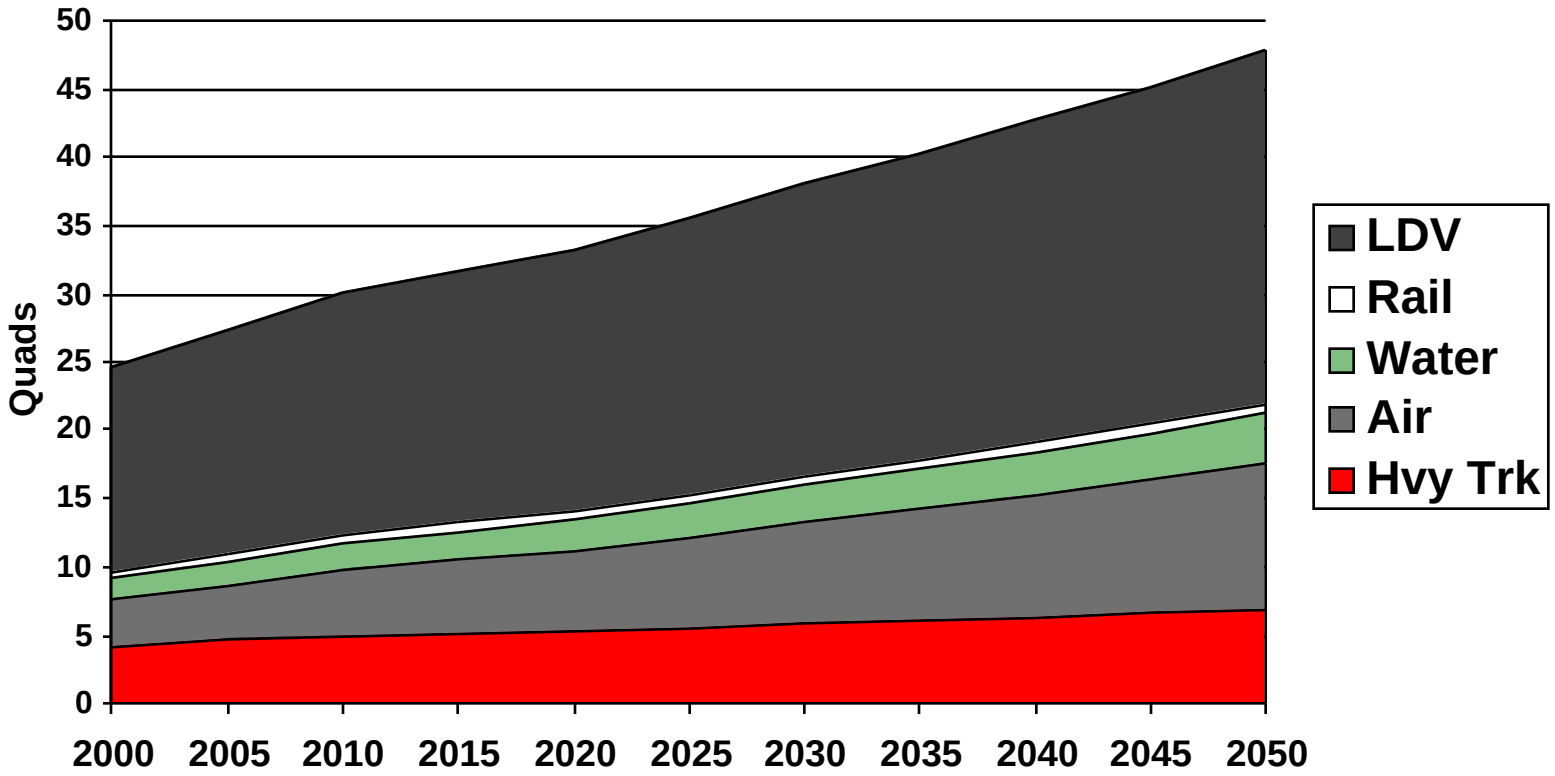
2050 Study

- Best case
- High gasoline prices
- 3X vehicles
- All federal goals reached for fuels

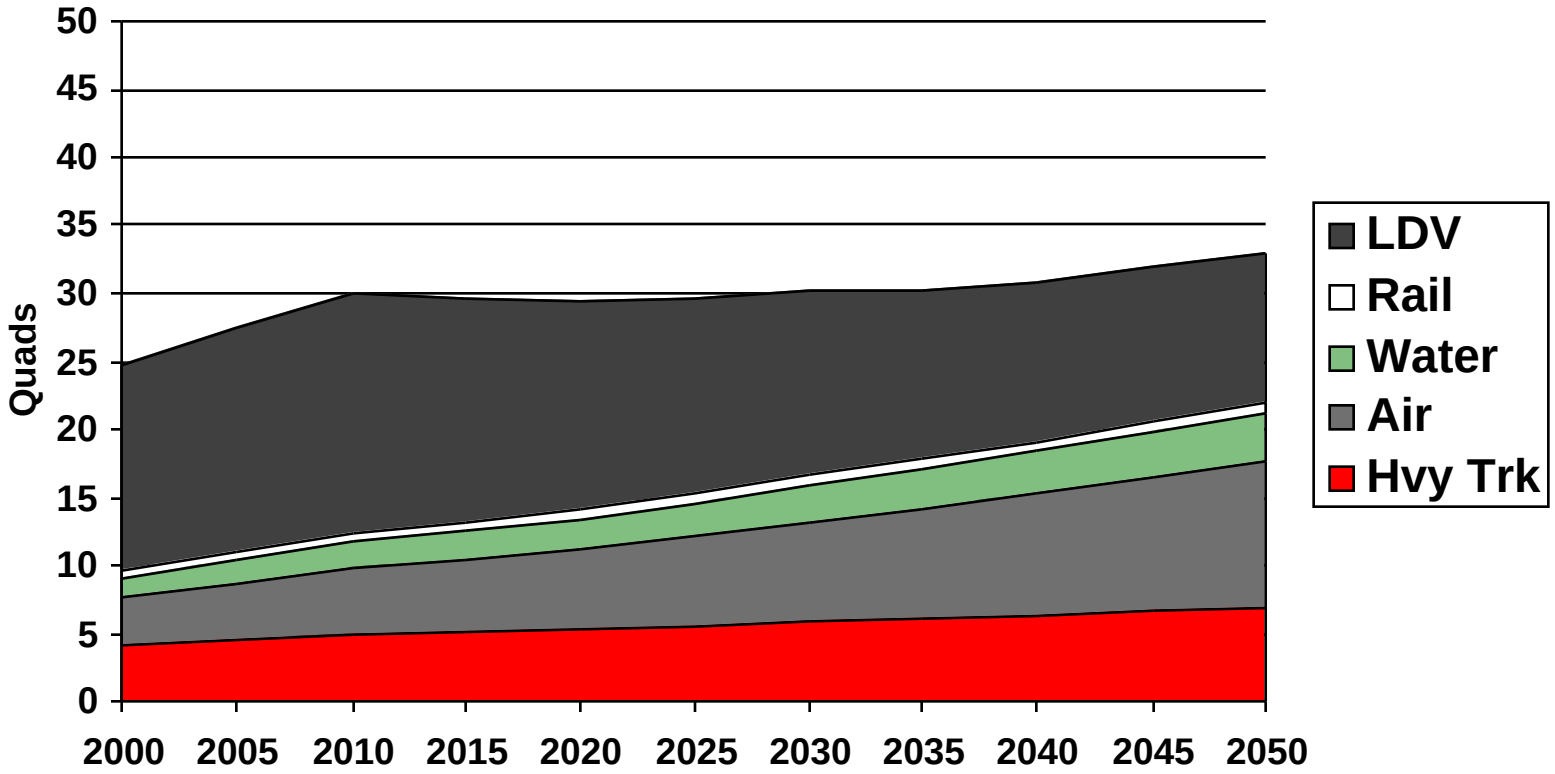
What's Next

- What gasoline price?
- What fuel economy?
- Technology goals?
- What ETOH assumptions?
- What Fischer-Tropsch assumptions?
- What hydrogen assumptions?
- Electricity fuel mixes?
- Heavy trucks component?
- Rest of transportation sector component?

Base Case Energy Use



“Best” Case Energy Use



Non-LDV Energy Use (quads)

	2000	2050	% Increase
Heavy Truck	4.29	7.05	64.3%
Air	3.39	10.53	210.6%
Water	1.50	3.63	142.0%
Rail	0.56	0.70	25.0%

Energy Changes (Quads) 2000 to 2050

	Base	Case 1	Net
Light Vehicles	11.0	-4.0	15.0
Heavy Vehicles	2.3	2.3	0.0
Air	7.1	7.1	0.0
Water	2.1	2.1	0.0
Rail	0.1	0.1	0.0
Total	22.6	7.6	15.0